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We certify that the attached English translation conforms essentially to the original French language.

Kim Vitray  
Operations Manager

Subscribed and sworn to before me this 15<sup>th</sup> day of November, 2004.

  
Tina Wuelfing  
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HEAT-TREATABLE, CORROSION-RESISTANT STEEL ALLOY

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The invention concerns a corrosion resistant steel that has a tensile strength of at least 155 kg/mm<sup>2</sup> and excellent corrosion resistance both in stressed and unstressed state. Moreover, the steel should be able to be cold worked without intermediate annealing.

The following steel composition is proposed in accordance with the invention:  
 up to 0.05% carbon,  
 up to 0.10% silicon,  
 up to 0.20% manganese,

up to 0.03% sulfur,  
up to 0.03% phosphorus,  
8-16% chromium,  
2-9% nickel,  
1-5% molybdenum,  
8-15% cobalt,  
0.20-0.7% titanium,  
with the remainder being iron with the usual contaminants.

The chromium component ensures the desired corrosion resistance. The addition of cobalt brings about an increase of hardness. At the same time the addition of cobalt prevents the development of delta-ferrite, without lowering the initial temperature for the formation of martensite, so that complete conversion to martensite in cooling from the annealing temperature is assured.

In addition, the steel alloy in accordance with the invention can additionally contain up to 0.15% aluminum, up to 0.2% niobium, up to 0.15% vanadium, up to 0.02% boron and up to 0.02% zirconium individually or as a mixture. Aluminum, niobium and vanadium in this case act as grain diminution agents and additional hardening agents, while boron and zirconium reduce precipitates at grain boundaries that lead to embrittlement.

An alloy composition that is characteristic for the steel in accordance with the invention is given below:

0.03% carbon,  
0.10% silicon,  
0.06% manganese,  
0.010% sulfur,  
0.003% phosphorus,  
4.30% nickel,  
12.20% chromium,  
4.50% molybdenum,  
15.0% cobalt,  
0.32% titanium,  
0.03% aluminum,  
0.10% niobium,  
0.0% vanadium,  
0.06% boron,  
0.01% zirconium.

The deformation and heat treatment steps described below are not objects of the invention.

Before forging, this steel alloy is annealed in a known way for at least 3 h at 1230°C and then forged in the range from 1200-1000°C. The steel billets are then reheated to 1100°C for further working. The primary deformation is carried out in the range from 1000-850°C, so that a fine-grained steel is obtained.

The heat treatment of the steel, which is also a known process, consists of heating it to 850°C and cooling it in air. This is followed by a hardening treatment in the range from 420-550°C. In some cases, i.e., when the alloying additives bring about a reduction of the initial temperature for the formation of martensite to under 200°C, a cold treatment at -80°C is necessary, upon which an annealing at 850°C takes place in order to maintain the desired strength values. Through careful monitoring of the chemical composition, however, the need for cold working can be avoided. Typical strength values both for the annealed state and for the fully hardened state are given in the following table for rods 25.4 mm in diameter. The results show the excellent strength and ductility of the steel in accordance with the invention.

In the following table PG means the proportionality limit, MS maximum stress, D strain and E the reduction of the cross-sectional area. A.C. means air cooling from the indicated temperature.

Test at 20°C—strength in kg/mm<sup>2</sup>

① Vorausgegangene Wärmebehandlung	PG	0,05%	0,10%	0,20%	0,50%	MS	D	E
② { 850°C 1 Stunde A.C. ....	20,4	46,7	58,5	71,6	89	99	26,0%	68,6%
850°C 1 Stunde A.C. und 440°C 16 Stunden A.C. ....	149	164	167	171	172	187	14,0%	48,8%

Key: 1 Prior heat treatment  
 2 850°C 1 h A.C.  
 850°C 1 h A.C.  
 and  
 440°C 16 h A.C.

Test at higher temperatures after 850°C, 1 h A.C., and 440°C 16 h A.C.—strength in kg/mm<sup>2</sup>

① Prüftemperatur	PG	0,05%	0,10%	0,20%	0,50%	MS	D	E
250°C .....	108	134	140	147	154	161	13,1%	38,0%
350°C .....	94	118	126	133	145	154	11,5%	39,8%
450°C .....	94	115	123	132	141	152	15,0%	41,9%

Key: 1 Test temperature

The low work hardening of the steel in annealed state causes this steel to be very well suited for processing by cold rolling. In addition, the steels in accordance with the invention have good resistance to corrosion and stress corrosion. For example, test rods that were stressed to just above the elasticity limit of the steel and were then immersed in a 3% salt solution, still remain undamaged after 20,000 h. Microscope examinations of the test rods after this experiment did not show any formation of pits or cracks on the surface. Other tensile test rods that were subjected to an industrial atmosphere and stressed up to 90% of the proof stress for 0.1% strain (154 kg/mm<sup>2</sup>) did not break until after 1500 h. These test results are considerably better than those of steels with similar tensile strength.

The steel can be machine processed without problem in annealed state (850°C A.C.). However, very hard high-speed steels are necessary for machining after hardening. In annealed state machining nearly up to the end dimensions is possible, since the changes of dimensions during hardening are negligibly small.

### Claims

1. Heat treatable, corrosion resistant steel alloy consisting of  
up to 0.05% carbon,  
up to 0.10% silicon,  
up to 0.20% manganese,  
up to 0.03% sulfur,  
up to 0.03% phosphorus,  
8-16% chromium,  
2-9% nickel,  
1-5% molybdenum,  
8-15% cobalt,  
0.20-0.7% titanium,  
with the remainder iron with conventional contaminants.

2. A steel alloy as in Claim 1, which additionally can contain  
up to 0.15% aluminum,  
up to 0.20% niobium,  
up to 0.15% vanadium,  
up to 0.02% boron,  
up to 0.02% zirconium,  
individually or as a mixture.
3. A steel alloy as in Claims 1 and 2, consisting of  
0.03% carbon,  
0.10% silicon,  
0.06% manganese,  
0.010% sulfur,  
0.003% phosphorus,  
4.30% nickel,  
12.20% chromium,  
4.50% molybdenum,  
15.0% cobalt,  
0.32% titanium,  
0.03% aluminum,  
0.10% niobium,  
0.0% vanadium,  
0.06% boron,  
0.01% zirconium.  
with the remainder being iron with the usual contaminants.